Measurement Systems

Lecture-21

Characteristics of measurement systems

Dr. Dhafer Manea Hachim AL-HASNAWI
Assist Proof
Al-Furat Al-Awsat Technical University
Engineering Technical College / Najaf
email:coj.dfr@atu.edu.iq

Characteristics of measurement systems

- The system characteristics are to be known, to choose an instrument that most suited to a particular measurement application.
- The performance characteristics may be broadly divided into two groups, namely ‘static’ and 'dynamic' characteristics.

Static characteristics:-

- The performance criteria for the measurement of quantities that remain constant, or vary only quite slowly.

Dynamic characteristics:-

- The relationship between the system input and output when the measured quantity (measured) is varying rapidly.

Static Performance Parameters

- **(i) Accuracy**
- Accuracy of a measuring system is defined as the closeness of the instrument output to the true value of the measured quantity (as per standards).
- For example, if a chemical balance reads 1 g with an error of 10^{-2}g, the accuracy of the measurement would be specified as 1%.
- Accuracy of the instrument mainly depends on the inherent limitations of the instrument as well as on the shortcomings in the measurement process.
- In other words, the accuracy of an instrument depends on the various systematic errors involved in the measurement process. For example, the accuracy of a common laboratory micrometer depends on instrument errors like zero error, errors in the pitch of screw, anvil shape, etc. and in the measurement process errors are caused due to temperature variation effect, applied torque, etc.
- The accuracy of the instruments (which represents really its inaccuracy) can be specified in either of the following forms:

a) $$\text{Percentage of true value} = \frac{(\text{Measured value - True value}) \times 100}{\text{True Value}}$$

b) $$\text{Percentage of full scale deflection} = \frac{(\text{Measured value - True value}) \times 100}{\text{Maximum scale value}}$$

(ii) Precision

- Precision is defined as the ability of the instrument to reproduce a certain set of readings within a given accuracy.
- Precision of an instrument is in fact, dependent on the repeatability. The term repeatability can be defined as the ability of the instrument to reproduce a group of measurements of the same measured quantity, made by the same observer, using the same instrument, under the same conditions. As mentioned before, the extent of random errors of alternatively the precision of a given set of measurements can be quantified by performing the statistical analysis.

- •Accuracy Versus Precision It may be noted that accuracy represents the degree of correctness of the measured value with respect to the true value. On the other hand, precision represents degree of repeat- ability of several independent measurements of the desired input al the same reference conditions. As mentioned before, accuracy and precision involved in a measurement are dependent on the systematic and random errors, respectively.. To illustrate this statement we take the example of a person doing shooting practice on a target. He can hit the target with the following possibilities as shown in Fig. 2.2(b).

  - 1. One possibility is that the person hits all the bullets on the target plate on the outer circle and misses the bull's eye (Fig. This is a case of high precision but poor accuracy.
  - 2. Second possibility is that the bullets are placed as shown in Fig. 2.2(b). In this case, the bullet hits are placed symmetrically with respect to the bull's eye but are not spaced closely. Therefore, this is case of good average accuracy but poor precision.
  - 3. A third possibility is that all the bullets hit the bull's eye and are also spaced closely
  - (Fig.2.2(a)]. As is clear from the diagram, this is an ease of high accuracy and high precision.
  - 4. Lastly, if the bullets hit the target plate in a random manner as shown in Fig. 2.2(d), then this is a case of poor precision as well as poor accuracy. Based on the above discussion, it may be stated that in any experiment the accuracy of the observations can be improved beyond the precision of the apparatus.

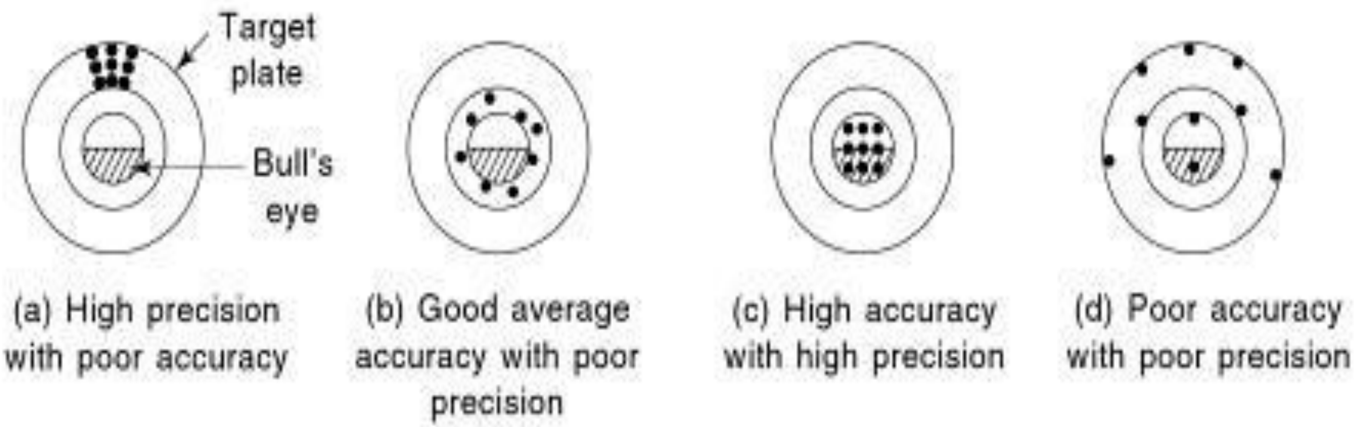

Fig. 2.2 *Illustration of degree of accuracy and precision in a typical target shooting experiment*

(iii) Resolution

- It is defined as the smallest increment in the measured value that can be detected with certainty by the instrument. In other words, it is the degree of fineness with which a measurement can be made. The least count of any instrument is taken as the resolution of the instrument. For example, a ruler with a least count of 1 mm may be used to measure to the nearest 0.5 mm by interpolation. Therefore, its resolution is considered as 0.5 mm. A high resolution instrument is one that can detect smallest possible variation in the input.

(iv) Threshold

- It is a particular case of resolution. It is defined as the minimum value of input below which no output can be detected. It is instructive to note that resolution refers to the smallest measurable input above the zero value. Both threshold and resolution can either be specified as absolute quantities in terms of input units or as percentage of full scale deflection.

(v) Static Sensitivity

- Static sensitivity (also termed as scale factor or gain) of the instrument is determined from the results of static calibration. This static characteristic is defined as the ratio of the magnitude of response (output signal) to the magnitude of the quantity being measured (input signal), i.e.

$$\text{Static sensitivity,} \qquad K = \frac{\text{change of output signal}}{\text{change in input signal}} = \frac{\Delta q_o}{\Delta q_i}$$

- Where qo and qi are the values of the output and input signals respectively.

(vi) Linearity

- A linear indicating scale is one of the most desirable features of any instrument. Therefore, manufacturers of instruments always attempt to design their instruments so that the output is a linear function of the input. However, linearity is never completely achieved and the deviations from the ideal are termed as linearity error.

(vii) Range and Span

- The range of the instrument is specified by the lower and upper limits in which it is designed to operate for measuring, indicating or recording the measured variable. The algebraic difference between the upper and lower range values is termed as the span of the instrument. The range of the instrument can either be unidirectional (e.g., 0 - 100°C) or bidirectional (e.g., -10 to 100°C) or it can be expanded type (e.g., 80 - 100°C) or zero suppressed (e.g., 5 - 40°C).

(viii) Hysteresis

- It is defined as the magnitude of error caused in the output for a given value of input, when this value is approached from opposite directions, i.e. from ascending order and then descending order.
- Whenever, there is solid contact between dry surfaces, stiction (due to Coulomb's friction) comes into play. It is defined as the force or torque necessary to initiate the motion of the instrument.
- After stiction, dynamic friction comes into play and the output-input characteristics of the instrument takes the shape of a closed curve known as the hysteresis loop shown in [Fig. 2.3(a)]. Further the shape of this loop changes if hydrodynamic or Viscous friction is present in the instrument system. In this case, the magnitude of the frictional force depends on the magnitude of the rate of change of input.
- In other words, the greater the rate of change of input, greater is the deviations in the friction values in the hysteresis loop [Fig.2.3 (b)]. However, if the rate of change of input goes to zero, the magnitude of the viscous friction also approaches zero, i.e. for steady state inputs, there is no error caused due to viscous friction. However, it causes a lag that needs to be compensated.

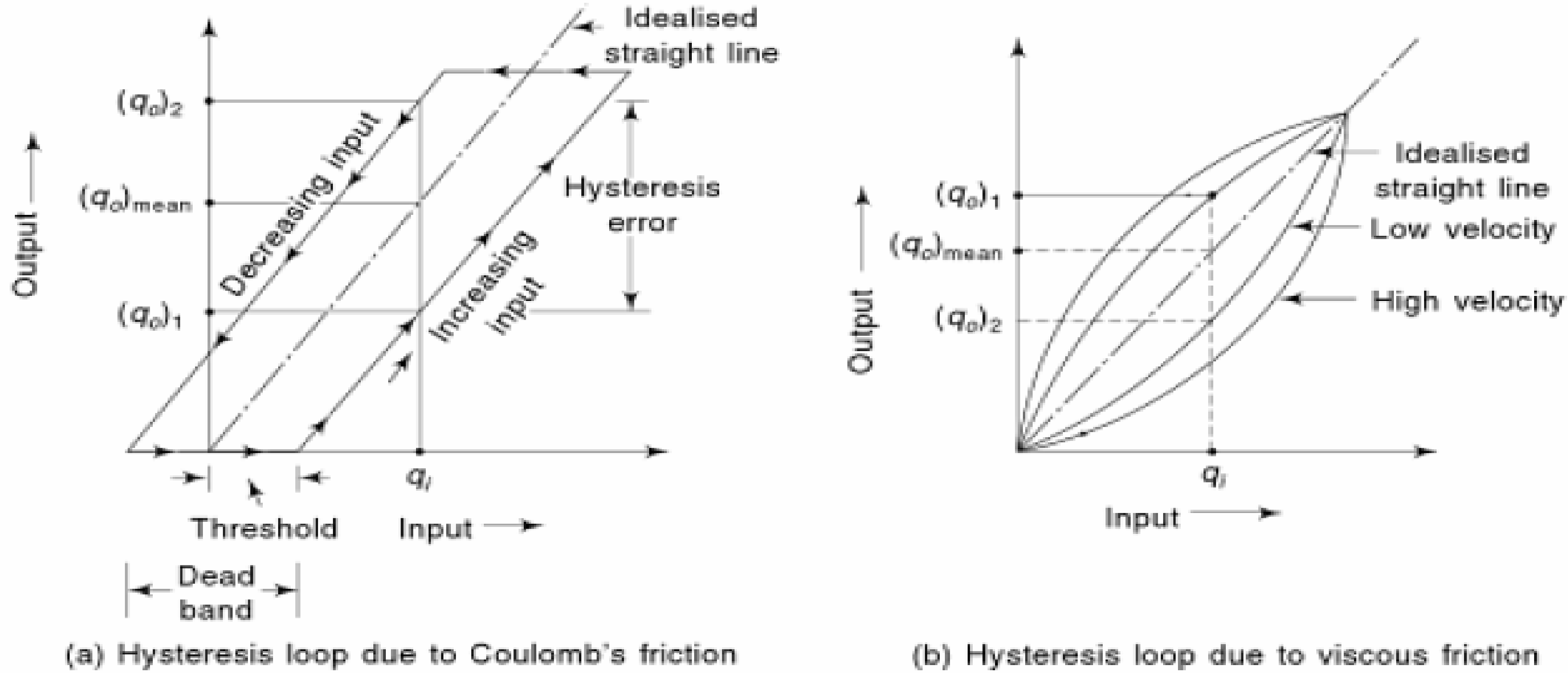

Fig. 2.3 Typical output-input curves showing hysteresis effect

- Hysteresis effects are best eliminated by taking the observations both for ascending and descending values of input and then taking the arithmetic mean. For example, in Fig, 2.3(a) and (b), for a value of input qi, the output in ascending order is (qo)1 and in descending order is (qo)2. Then the mean value is:

$$(q_o)_{mean} = \frac{(q_o)_1 + (q_o)_2}{2}$$